The Progressive Fish-Culturist 56:301–303, 1994
American Fisheries Society

Vaterite Sagittal Otoliths in Hatchery-Reared Juvenile Red Drums

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Abstract.—Aberrant otoliths, although uncommon, have been reported in many fish species. We examined sagittae, lapilli, and asterisci from 1,140 wild and 1,723 hatchery-reared juvenile red drums (*Sciaenops ocellatus*). Aberrant sagittae were found in 20 hatchery-reared fish. These otoliths, which appeared to be formed from a conglomeration of small spheres, were composed of the vaterite polymorph of calcium carbonate instead of the aragonite polymorph normally found in sagittae. No internal ring structure was present; however, gross external morphological features were similar to normal sagittae. Affected red drums had one normal sagitta, and all lapilli and asterisci were normal. No abnormal sagittae were found in wild fish.

Anomalous otoliths have been reported several times in the literature. Palmork et al. (1963) found a morphological and a structural aberration in sagittae from Atlantic cod (*Gadus morhua*). Sagittal aberrations have also been found in walleye pollock (*Theragra chalcogramma*), rainbow trout (*Oncorhynchus mykiss*), and sohachi flounder (*Cleisthenes pinetorum*) (Mugiya 1972; Miyake 1992). Blacker (1974) reported the occurrence of crystallized and partially crystallized calcitic otoliths in cod, plaice (*Pleuronectes platessa*), and haddock (*Melanogrammus aeglefinus*) from the North Atlantic. Radtke (1978) found dual nuclei in larval striped bass (*Morone saxatilis*), and Morales-Nin (1985) reported crystalline otoliths in cusk-eels (Ophidiidae). Abnormal crystallization has been found in the sagittae of chinook salmon (*Oncorhynchus tshawytscha*) and pollock (*Pollachius virens*) (Gauldie 1986; Strong et al. 1986; Murray 1993).

We report the occurrence of anomalous sagittal otoliths in hatchery-reared juvenile red drums (*Sciaenops ocellatus*). The anomalous otoliths had normal external features and normal birefringent properties, but internally they were composed of amorphous concretions shaped as small spheres. Only one of the two sagittae was abnormal in each of the 20 affected fish (Figure 1). Rostra, sulci, and marginal crenulations were clearly visible and normally located, and no deficiencies in the saccular membranes were detected. Anomalous sagittae were equally prevalent on both sides of the fish we examined, and no abnormal lapilli or asterisci were found. Otolith growth increments were not visible in either whole or transverse sectioned aberrant otoliths. X-ray diffraction analysis revealed that the abnormal sagittae were composed of the vaterite polymorph of calcium carbonate instead of the aragonitic polymorph that composes normal sagittae and lapilli (Carlström 1963). We examined 1,723 hatchery-reared and 1,140 wild red drums and found 20 (1.16%) hatchery-reared juveniles with one anomalous sagitta. We found no abnormal otoliths in wild fishes. Eighteen collections of hatchery-reared red drums were examined and abnormal otoliths were found in only four collections (N = 21, 382, 450, and 493). The occurrence of fishes in these collections with anomalous otoliths ranged from 0.79 to 4.76% (mean, 2.24%). These fish were 6–7 weeks old and were 18.5–29.4 mm (mean, 21.9 mm) standard length (SL).

Several authors have suggested reasons for the occurrence of abnormal otoliths. Morales-Nin (1985) hypothesized that a local alteration of the sacculus caused crystalline otoliths in cusk-eels. Gauldie (1986) noted a significant relation between temperature and the occurrence of aberrant otoliths in chinook salmon; Strong et al. (1986) suggested that, in pollock, either random calcitic crystallization occurred or that mechanical damage to the macular cells adjacent to the regions of calcitic deposition caused aberrant crystallization of sagittae. Mugiya (1972) proposed that an alteration of the organic and mineralization phases might be the cause of vateritic sagittae in the walleye pollock, rainbow trout, and sohachi flounder. Blacker (1974) did not speculate as to the cause

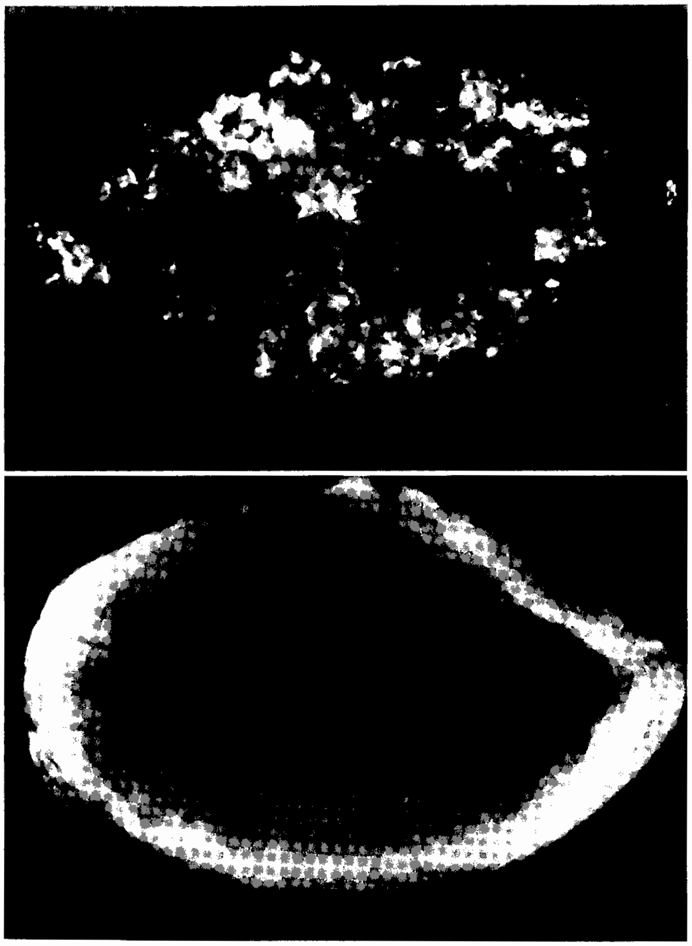

FIGURE 1.—Sagittae of hatchery-reared juvenile red drum spawned during October 1990. The aberrant sagitta (top), from 21.2-mm standard length (SL) fish, is composed of vaterite. The normal sagitta (bottom), from 24.8-mm SL fish, is composed of aragonite. Sectioning a normal sagitta reveals significantly more internal ring structure than visible in this whole mount, whereas no internal ring structure is detectable in a sectioned aberrant sagitta. Bar = 0.5 mm (for both panels).

of crystallized and partially crystallized calcitic otoliths found in cod, plaice, and haddock, but his reported percent of occurrence, 1.0–5.0%, is similar to the percentage of abnormal otoliths that we found in hatchery-reared juvenile red drums (0.79–4.76%).

Possible causes of abnormal sagittae found in hatchery-reared juvenile red drums include nutritional deficiencies, chemical poisoning of the crystal forming process, and decreased survivability of similarly affected wild fish. Hatchery protocol offers some support for nutrition deficiencies as the cause. The hatchery, operated by the Florida Department of Natural Resources, is located in Port Manatee on the lower Tampa Bay. Hatchery production protocol is fairly standard; adult fishes spawn in indoor tanks, and the eggs are collected and moved to 0.5–1.0 acre outdoor ponds within 3 d of hatching. Ponds are filled with natural seawater containing initial prey species from the adjacent bay. The level of natural prey in the outdoor ponds is enhanced, and commercial fish ration is provided as soon as the natural prey is depleted, usually within 10 d of stocking. The hatchery is located in an area of rich, naturally occurring phosphate deposits, which are extensively mined and processed. During periods of high rainfall, groundwater intrudes (W. Halstead, Florida Marine Research Institute, Stock Enhancement Facility, personal communication), and the phosphate-rich groundwater may introduce phosphate into the ponds. Hatchery broodstock is captured in Tampa Bay; consequently, genetic factors are probably similar in both wild and hatchery populations. Thus, nutritional history and water quality exposure are the potential major differences between wild and hatchery-reared red drums.

High levels of phosphate in the water can cause chemical poisoning of the crystal formation process in otoliths. The introduced phosphate may enter the circulatory system of the fish and eventually cause the endolymphatic fluid in the sacculus to disrupt aragonitic crystallization (A. P. Wheeler, Clemson University, personal communication). The high variability of abnormality rates in fish from different ponds supports the hypothesis of environmental causation.

A third hypothesis to explain the presence of irregular otoliths in only hatchery-reared fish is that wild fish with irregular otoliths either do not survive or they experience lower survival rates than fish with normal otoliths. However, the occurrence of abnormal otoliths in wild fishes (Palmork et al. 1963; Mugiya 1972; Blacker 1974; Morales-Nin 1985; Strong et al. 1986; Miyake 1992) argues against strong differential survival effects. Furthermore, the size distribution of fish with aberrant otoliths was similar to the total size distribution of the collections they came from, suggesting that fish with irregular otoliths did not suffer a growth (and perhaps a survival) disadvantage.

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